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(54) Heat transfer surface.

(57) A heat transfer surface for boiling a liquefied gas formed by spraying a particulate mixture of metal and a plastic material onto a thermally conductive surface to form a coating comprising particles of plastic embedded in metal and heating to a temperature sufficient to volatilize the plastic material thereby forming pores in the metal coating.

EP 0 303 493 A1

Description

HEAT TRANSFER SURFACE

This invention relates to heat transfer surfaces and to methods for making such surfaces.

When boiling a liquefied gas (that is as defined herein, the liquid phase of substance which has a boiling point of 20°C or below (at 1 atmosphere absolute), the temperature difference between the boiling liquid and the heat transfer surface employed to heat the liquid is defined by the quantity Q/h A where Q/A is the heat flux, that is the heat absorbed in boiling the liquefied gas, A is the nominal surface area of the surface at which the liquefied gas is boiled, and h is a quantity known as the boiling heat transfer coefficient. Accordingly for given values of Q and A, the temperature difference decreases with increasing boiling heat transfer coefficient. There are many proposals in the art for increasing the boiling heat transfer coefficient of the heat transfer furface of a heat exchanger or condenser-reboiler by providing such surfaces with nucleation sites for the formation of vapour bubbles. Methods for forming such nucleation sites typically involve working the surface to provide cavities or channels therein, or providing a surface with a porous coating. Examples of such improved boiling surfaces are given in, for example, US patent specification 3 384 154, 3 457 990 and Re-issue 30077 and UK patent application No. 2 155 612. A general review of such surfaces is given in a paper entitled "The Evolution of Enhanced Surface Geometries for Nucleate Boiling", Ralph L Webb, Heat Transfer Engineering, Volume 2 Nos. 3 to 4, January to June 1981, at pages 46 to 69.

Notwithstanding the wide range of known heat transfer surfaces with nucleate boiling sites, there is a need for new and improved surfaces.

It is an aim of the invention to provide a new heat transfer member having a heat transfer surface bearing a multiplicity of nucleate boiling cavities, wherein the porosity of the surface and the average size of the pores or cavities are able to be varied independently of one another.

According to the present invention there is provided a heat transfer member for boiling a liquefied gas having a heat transfer surface comprising a multiplicity of open pores, wherein said surface is formed by spraying a particulate mixture of metal and plastics materials onto a surface of a thermally conductive substrate to form a coating comprising particles of plastics embedded in metal on the said surface, and heating the thus formed coating to volatise or otherwise remove the plastics material and thereby form the pores in the coating.

The invention also provides a method of making a heat transfer surface for boiling a liquefied gas comprising spraying a particulate mixture of metal and plastics material onto a surface of a thermally conductive substrate to form a coating comprising particles of plastics embedded in metal on the said surface, and heating the coating to volatise or otherwise remove the plastics material and thereby form the pores in the coating.

The percentage porosity of the coating dep nds on the mass ratio of plastics powder to metal powder. The average size of the pores depends largely on the average size of the plastics particles. Accordingly the invention enables the porosity to be varied independently of the average pore size and thus enables there to be prepared a heat transfer surface specially tailored to the properties of the liquefied gas being boiled.

Typically, the plastics particles can have an average size in the range 15 to 150 microns. Typically, the mass ratio of metal particles to plastic particles in the mixture that is sprayed onto the surface of the substrate has a ratio in the range of 4 : 1 to 1 : 1. The coating may typically have a porosity of from about 20 to 50%. In conducting the spraying operation it needs to be taken into account that the metal will have a higher specific gravity than the plastics, and that some of the plastics will typically be lost during spraying. For example, spraying a surface with a mixture of aluminium and plastics having a mass ratio of 1:1 will typically produce a coating having about 55% porosity.

The average size of the metal particles is not critical to the invention and may be lower or higher than the average size of the plastics particles. Similarly, the thickness of the coating is not critical to the invention. In our experiments, we have prepared coatings comprising a single porous layer 5, 10 and 15 thousands of an inch in depth, and coatings comprising two such porous layers, one layer having a different average pore size from the other.

The plastics and metal particles may each have a regular or irregular geometry but their flow properties must allow their use in a spray coating process.

Heat transfer members according to the invention typically have surfaces that comprise a network of open, re-entrant pores or cavities having an average size in the range 15 to 150 microns (and more typically a size in the range 15 to 50 microns).

The mixture of plastics and metal is preferably sprayed onto the substrate by plasma spraying. Alternatively, flame spraying may be employed. The spraying process may be controlled so as to give the axes of the pores any desired orientation, although typically each pore has an axis perpendicular to the surface of the substrate.

Generally, the mixture comprises separate particles of plastics and metals, although if desired the mixture may comprise composite particles of plastics and metal.

The metal may have the same or a different composition from that of the substrate. Typically, the metal comprises aluminium or copper or an alloy based on aluminium or copper. It is possible to select the plastics particles from a wide range of different plastics materials, but in our experiments we have used polyester particles.

Once the coating is formed, the structure is heated to volatilise th plastics. The temperature used needs to be sufficient cleanly t remov the

platics material, that is to volatalise it without leaving any carbonaceous or other deposit.

In the event that the plastics particles are polyester, a temperature in the range 500 to 600°C is preferably employed to effect volatalisation of the deposited polyester.

The substrate is preferably a metal plate which may be employed as a heat transfer surface in a liquefied gas boiler particularly a condenser-reboiler for use in the double column of an air separation plant.

The method and apparatus according to the invention will now be described by way of example with reference to the accompanying drawings, in which :

Figure 1 is a schematic plan view of a heat transfer member according to the invention;

Figure 2 is a schematic section through the line II in Figure 1.

Figure 3 is a schematic section of an alternative heat transfer member according to the invention, and

Figure 4 is a graph illustrating the variation in delta T of a heat transfer member according to the invention with the heat flux Q/A

Figure 5 is an electronmicrograph of the surface of a heat transfer member according to the invention showing the surface at a magnification of 500 times actual size.

Figure 6 is an electronmicrograph similar to Figure 5 but at a magnification of 5000 times actual size.

Figures 1 to 3 of the drawings are not to scale.

Referring to Figure 1 of the drawings, the heat exchange member comprises a plate 2 of heat conductive metal usually alluminium or copper. As shown in Figure 2 the plate 2 bears a layer 4, typically having a thickness in the range 0.1mm to 1.0mm of porous metal, which is typically of the same composition as the plate 2. In an alternative embodiment of the invention illustrated in Figure 3, there are a plurality of layers of porous metal. Typically, the inner layer 6 has a smaller average pore size than the outer layer 8, although if desired, this difference in the average pore size may be reversed.

In one example of the method according to the invention an aluminium plate 50 mm by 50 mm was provided with a porous aluminium-silicon coating by the following procedure. The surface was first cleaned by shot-blasting. The surface was then plasma sprayed with a proprietary blend of silicon-aluminium alloy and polyester powder (Metco 601 NS). The plasma was formed by supplying to the spraying chamber argon at a pressure of 100 psig and hydrogen at a pressure of 50 psig. Spray rates in the range 5 pounds to 7 pounds per hour of the mixture of plastics powder and metal powder were employed. Continuous matrices of aluminium with dispersed particles of polyester were formed on the surface of the aluminium samples. The polyester was then driven off by heating in a vacuum for two h urs at a temperature in the order of 540°C. This left surfac s n each sample c mprising a network of pen re-entrant pores having axes generally dis p s d at right-angles to the surface of the substrat .

The boiling heat transfer co-efficient of a sample according to the invention and one comprising merely a polished surface of aluminium were then measured by fitting each sample in turn to a heater block and then submerging the block in liquid nitrogen. Constant copper thermocouples were employed to measure the temperature difference between the surface and the boiling liquid nitrogen, while the electrical power supplied to the surface was also measured.

The variation of Q/A and h with delta T for the two samples is shown in Figure 4 of the accompanying drawings. It can be seen that the sample according to the invention has superior properties to the polished aluminium surface.

Figures 5 and 6 are electromicrographs of a heat transfer surface formed by plasma spraying a mixture of 60% by weight of aluminium and 40% by weight of polyester onto an aluminium substrate and then baking the resulting coated substrate for two hours at 500°C. The coating had a thickness of 0.38 mm.

Figure 5 shows the coated surface at a magnification of 500 times actual size, and Figure 6 shows the surface at a magnification of 5000 times actual size.

Claims

1. A heat transfer member for boiling a liquefied gas having a heat transfer surface comprising a multiplicity of open pores wherein said surface is formed by spraying a particulate mixture of metal and plastics material onto a surface of a thermally conductive substrate to form a coating comprising particles of plastics embedded in metal on the said surface, and heating the thus formed coating to volatilise or otherwise remove the plastics material and thereby form the pores in the coating.

2. A heat transfer member as claimed in claim 1, in which the average pore is size is in the range 15 to 50 microns.

3. A heat transfer member as claimed in claim 1 or claim 2, in which the coating has a porosity of from 20 to 50%.

4. A heat transfer member as claimed in any one of the preceding claims, in which the metal and the substrate each comprise aluminium, copper or an alloy of aluminium or copper.

5. A heat transfer member as claimed in any one of the preceeding claims, in which the coating has a depth in the range of 0.1 to 1.0mm

6. A boiler for a liquefied gas, including a heat transfer member or members as claimed in anyone of the preceding claims.

7. A method of making a heat transfer surface member for boiling a liquefied gas comprising spraying a particulate mixture of metal and plastics material nt a surfac of a thermally c nductive substrate to form a coating comprising particles of plastics embedded in metal on the said surface, and heating the coating to

volatilise or otherwise remove the plastics material and thereby form the pores in the coating.

8. A method as claimed in claim 7, in which the mixture includes plastics particles having an average size in the range 15 to 150 microns.

9. A method as claimed in claim 7 or claim 8, in which the ratio (by mass) of metal to plastics in the mixture is in the range 1:1 to 4:1.

10. A method as claimed in any one claims 7 to 9, in which the coating is deposit d by plasma spraying.

11. A method as claimed in any one of claims 7 to 9, in which the plastics material comprises a polyester.

FIG. 1

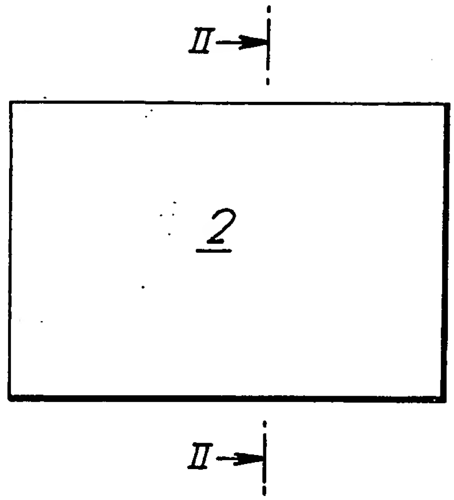


FIG. 2

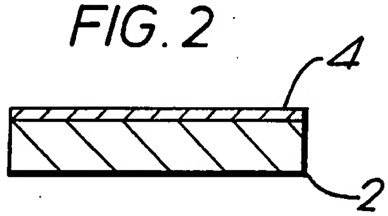


FIG. 3

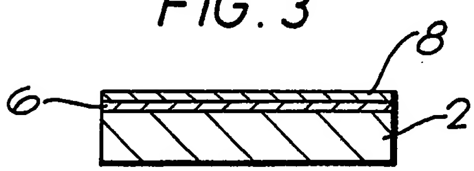
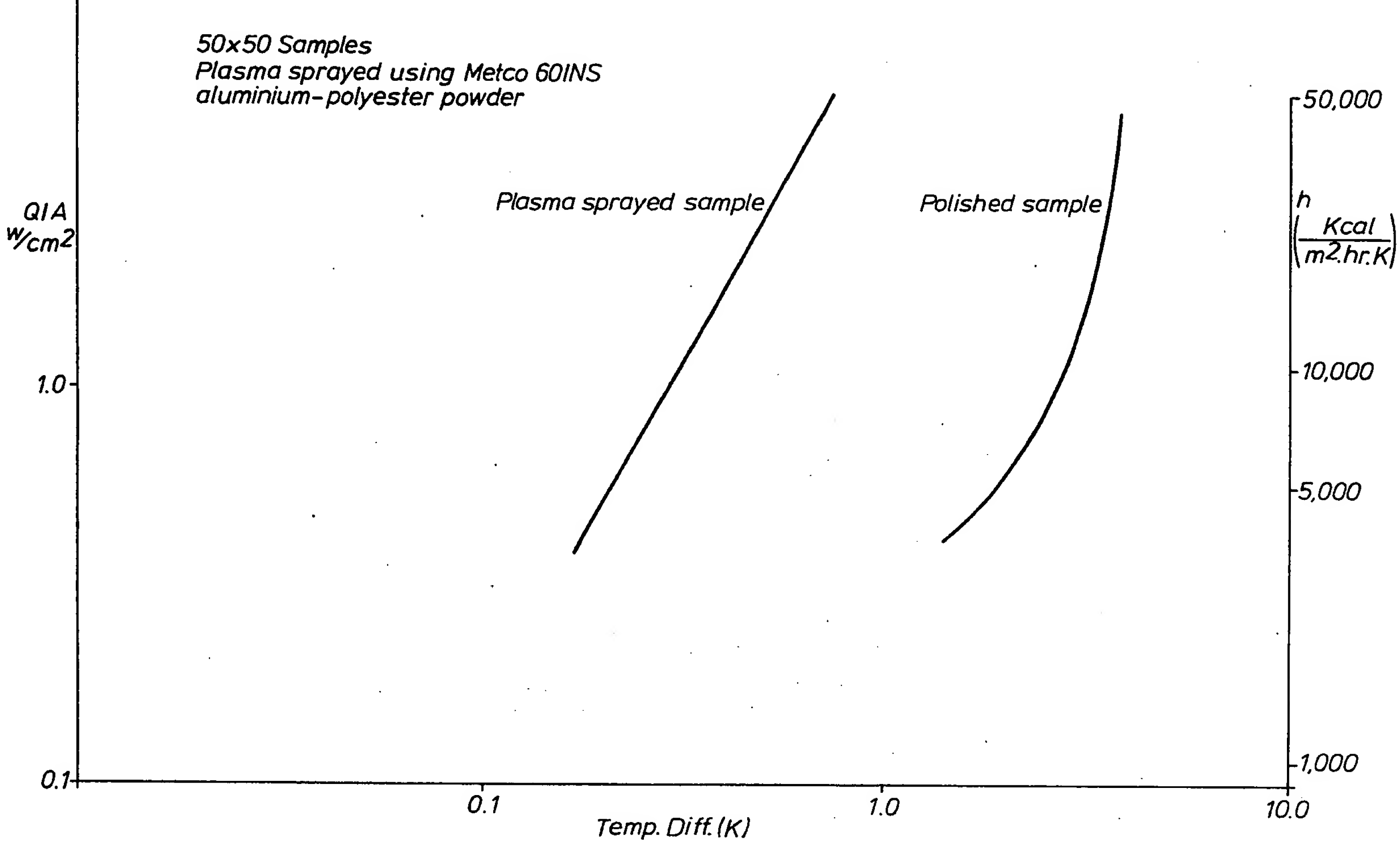


FIG. 4


50x50 Samples
Plasma sprayed using Metco 60INS
aluminium-polyester powder
Plasma sprayed sample
Polished sample
Q/A
W/cm2
10.0
1.0
0.1
0.1
1.0
10.0
Temp. Diff. (K)
h
(Kcal / m2.hr.K)
50,000
10,000
5,000
1,000

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 88 30 7468

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	DE-A-2 227 747 (UNIVERSAL OIL) * Page 6, lines 8-17,30,31; page 9, lines 13-17; page 10, lines 24-31; page 11, lines 1-21; claims 1,5-7,9,10,12-14 *	1,3-5,7-9	F 28 F 13/18 C 23 C 4/04 C 23 C 4/18 // B 05 D 1/10
Y		2,6,10,11	
Y	FR-A-2 299 611 (THE GATES RUBBER) * Page 11, lines 10-23; claim 1 *	2	
Y	US-A-3 523 577 (MILTON) * Column 11, lines 41-55; figure 8 *	6	
Y	GB-A-2 152 079 (UNITED TECHNOLOGIES) * Abstract; page 1, lines 21-25; page 2, lines 31-33; claims 1,3 *	10	
Y	US-A-3 723 165 (LONGO et al.) * Abstract; claims 1-5 *	11	

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

F 28 F
C 23 C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	12-10-1988	HOERNELL, L.H.

CATEGORY OF CITED DOCUMENTS

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